Managing Decision Uncertainty Using the Triad Approach

Deana M. Crumbling, M.S.
Technology Innovation Office
U.S. Environmental Protection Agency
Washington, D.C.
(703) 603-0643
crumbling.deana@epa.gov

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USEPA
Technology Innovation Office

- Advocates for better technologies and strategies to clean up contaminated sites:
  - Site investigation/characterization
  - Site remediation
  - Monitoring during or after remedial action
- Acts as an agent for change
  - Disseminates others' good ideas
- Cleanup Information Website: http://cluin.org

Take-Home Message # 1

Using
SOUND SCIENCE
when evaluating contaminated sites means that the
the scale of data generation and interpretation
must closely "match"
the scale of project decisions being based on that data.

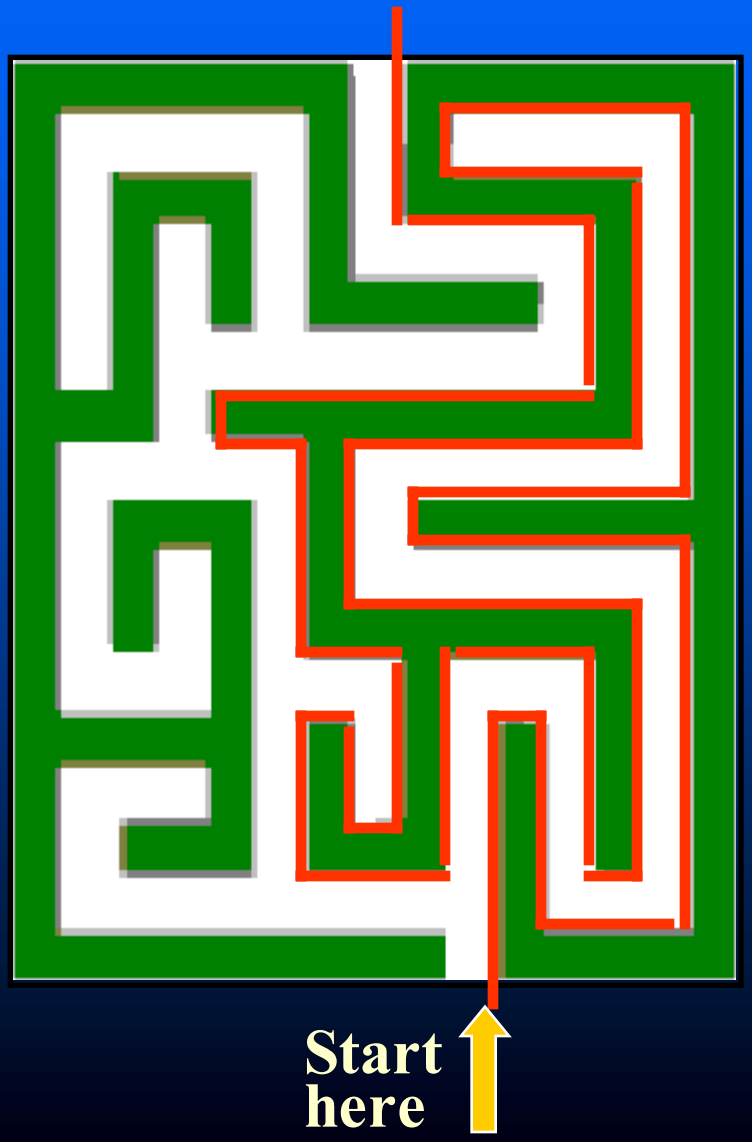
"Sound science" also requires managing uncertainty,
since an exact match usually is not feasible.

Take-Home Message # 2

- The Triad Approach seeks to institutionalize uncertainty management through holistic integration of innovative data generation and interpretation tools
- **Triad Approach** = Integrates **systematic project planning**, a **dynamic work plan strategy**, and **real-time analysis** as applied to wastes and contaminated sites to ⇓ time & costs and ⇑ decision certainty
- Theme for the Triad Approach = Explicitly identify and manage the largest sources of decision error, especially the sampling representativeness of data

Characterization & Cleanup Strategy: Where We've Been

The Past: A Process-Driven Approach



Mandate to Superfund Program
Create program to cleanup up sites with little experience, tools, or knowledge to do so!

Similar to finding one's way through a maze when the exit is not marked

- Solution to both: Use a rote one-size-fits-all process to get through the maze to the exit.
- Caveat: You cannot expect it to be a resource-efficient trip.

Analogous algorithm: "define the nature and extent of contamination" without using project decision goals to select the scale of data generation

2 3

1

2

One-size-fits-all lab analyses

2 1

We need more information

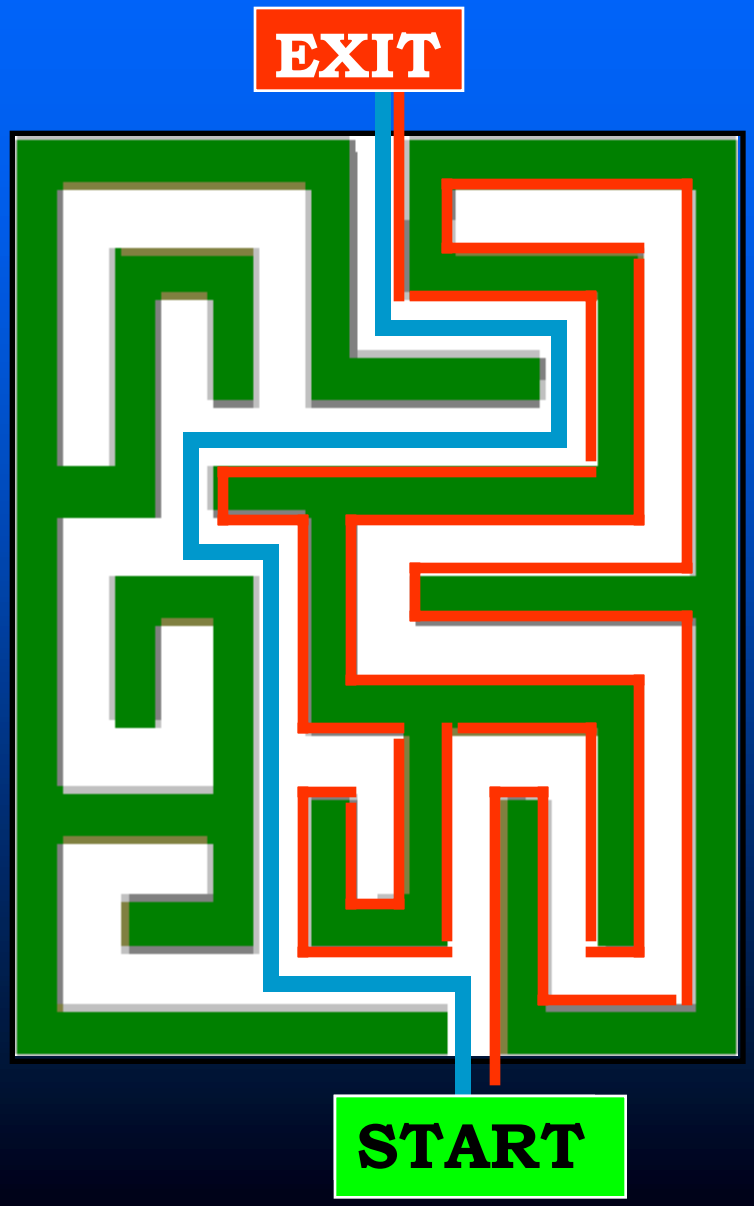
2

1

REPORT

Characterization & Cleanup Strategy: Where We Are Heading

The Future: Toward a Better Strategy



Proven Effective:

- Project planning (vs. process)
- Multidisciplinary team
- Stakeholders involved
- Create opportunities for real-time decision-making to save time and $$
- Real-time decisions need real-time data & uncertainty mgt
- Project-specific CSM to plot resource-effective course

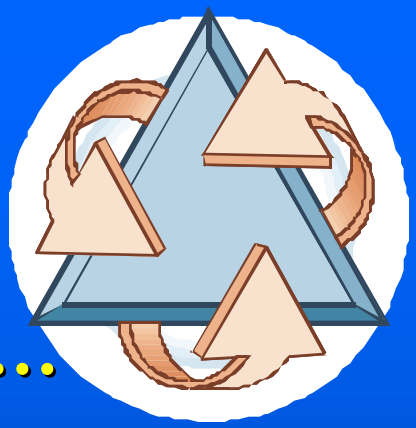
A Systems Approach Framework
The Triad Approach

Systematic Project Planning

Dynamic Work Plan Strategy

Real-time Measurement Technologies

Unifying Concept for Triad:
Managing Uncertainty



Systematic planning is used to proactively…

- **Manage uncertainty about project goals**
  - Identify decision goals with tolerable overall uncertainty
  - Identify major uncertainties (cause decision error)
  - Identify the strategies to manage each major uncertainty
- **Manage uncertainty in data**
  - **Sampling uncertainty:** manage sample representativeness
  - **Analytical uncertainty:** especially if field methods are used
- **Multidisciplinary expertise critical**
  - **A TEAM** is the best way to bring needed knowledge to bear

Dynamic Work Plan Strategy

- Real-time decision-making "in the field"
  - Evolve CSM in real-time
  - Implement pre-approved decision tree using senior staff
  - Contingency planning: most seamless activity flow possible to reach project goals in fewest mobilizations
- Real-time decisions need real-time data
  - Use off-site lab w/ short turnaround?
    - » Use screening analytical methods in fixed lab?
  - Use on-site analysis?
    - » Use mobile lab with conventional equipment?
    - » Use portable kits & instruments?

Mix And Match

In all cases, must generate data of known quality

Generating Real-time Data Using Field Methods

Manage Uncertainty through Systematic Planning

- **Need clearly defined data uses—tie to project goals**
- **Understand dynamic work plan—branch points & work flow**
- **Project-specific QA/QC protocols matched to intended data use**
- **Select field analytical technologies to**
  - Support the dynamic work plan (greatest source of $$ savings)
  - Manage sampling uncertainty (improves decision quality)
- **Select fixed lab methods (as needed) to**
  - Manage uncertainties in field data (just ONE aspect of QC for field data)
  - Supply analyte-specific data and/or lower quantitation limits (as needed for regulatory compliance, risk assessment, etc.)

Updating the Data Quality Concept as a Tool to Achieve Decision Quality

Data is Generated on Samples

Perfect Analytical Chemistry + **Non-Representative Sample**

"BAD" DATA

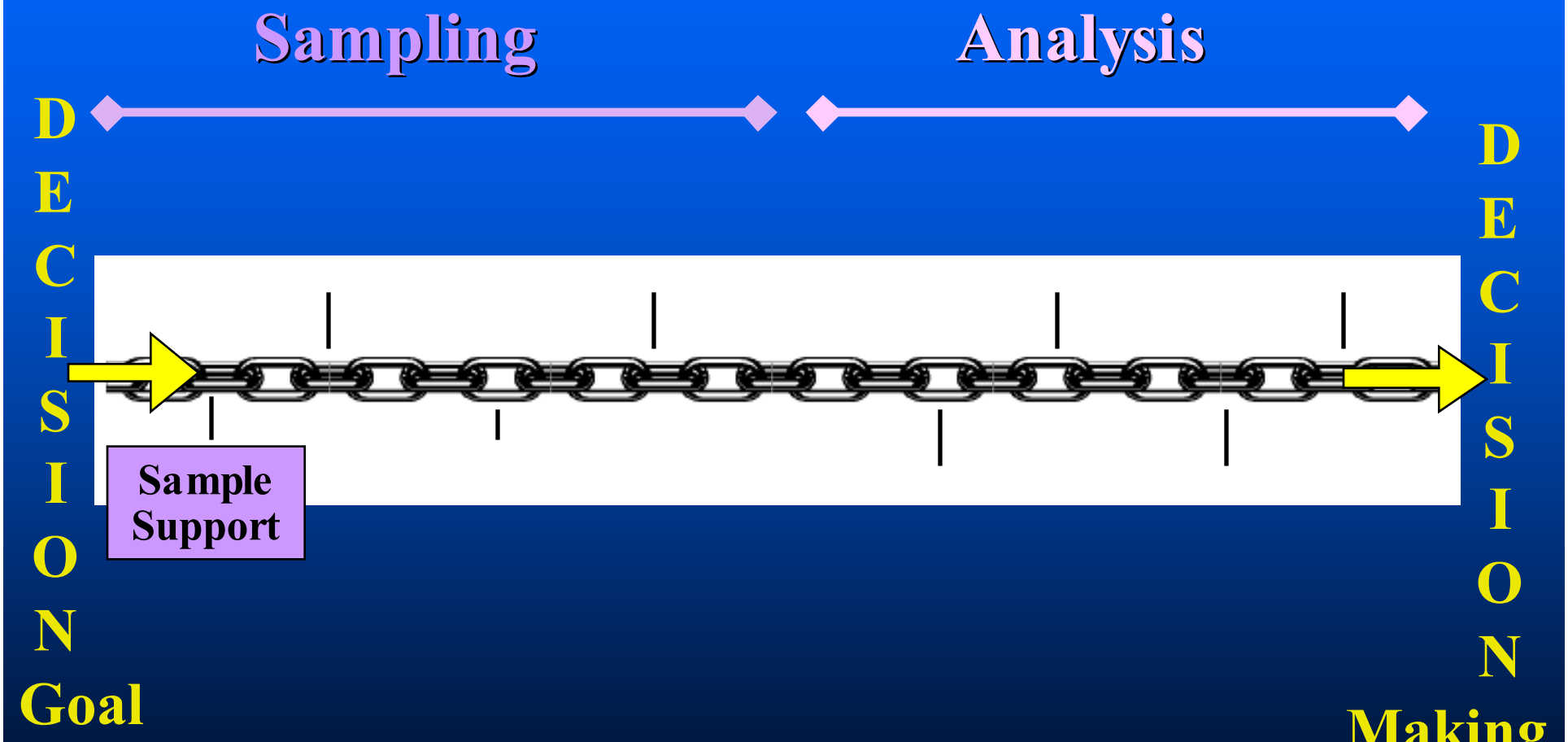
Distinguish:
Analytical Quality from Data Quality

What is "Data Quality"?

Data Quality = The ability of data to provide information that meets user needs

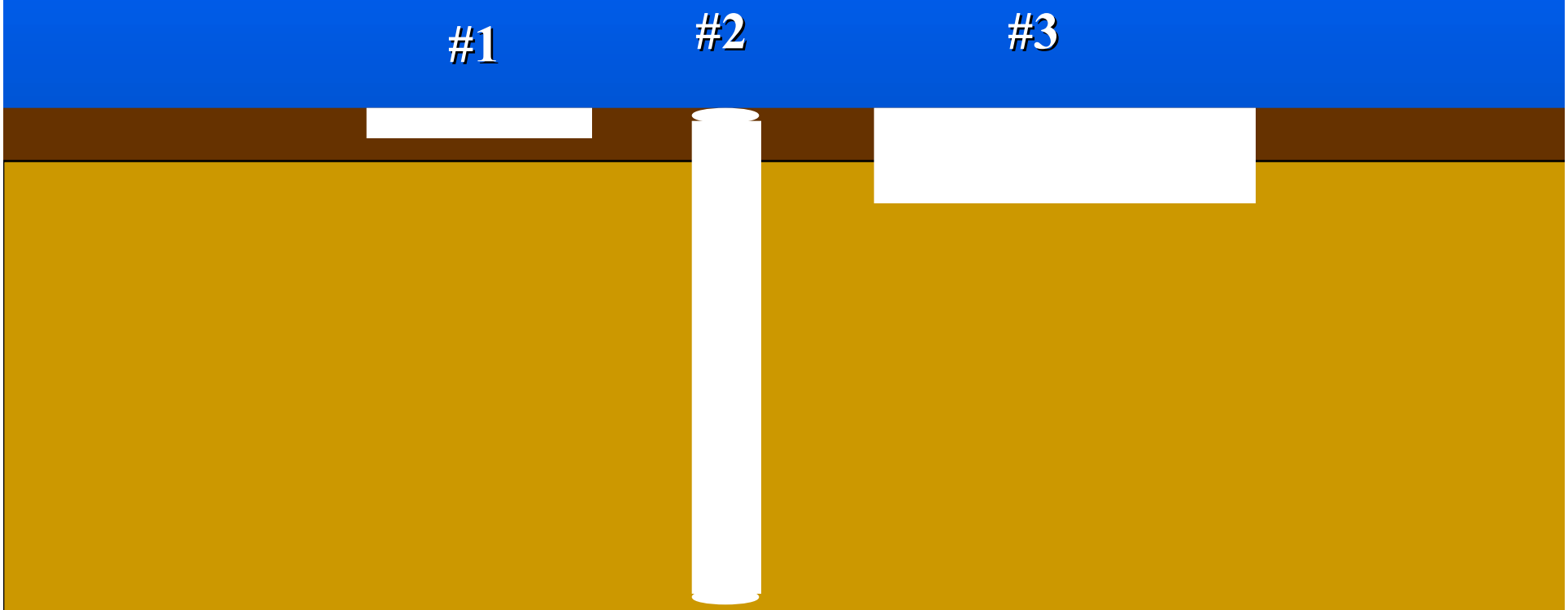
- Users need to make correct decisions
- Data quality is a function of data's…
  - ability to represent the "true state" in the context of the decision to be made
    - » The decision defines the scale for the "true state"
  - information content (including its uncertainty)

The Data Quality "Chain"



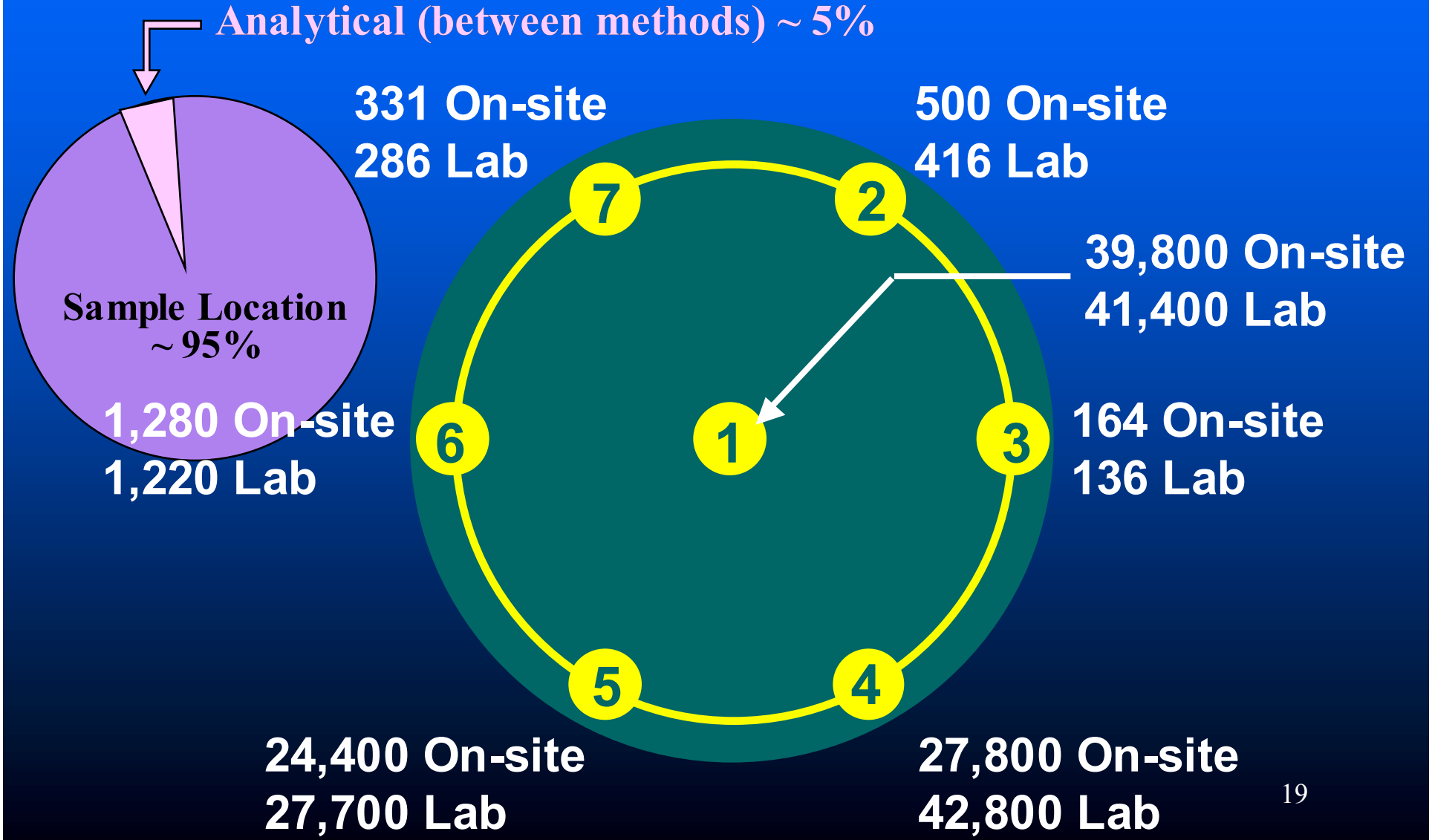
Sample Support: Critical to Representativeness

Sample Volume & Orientation

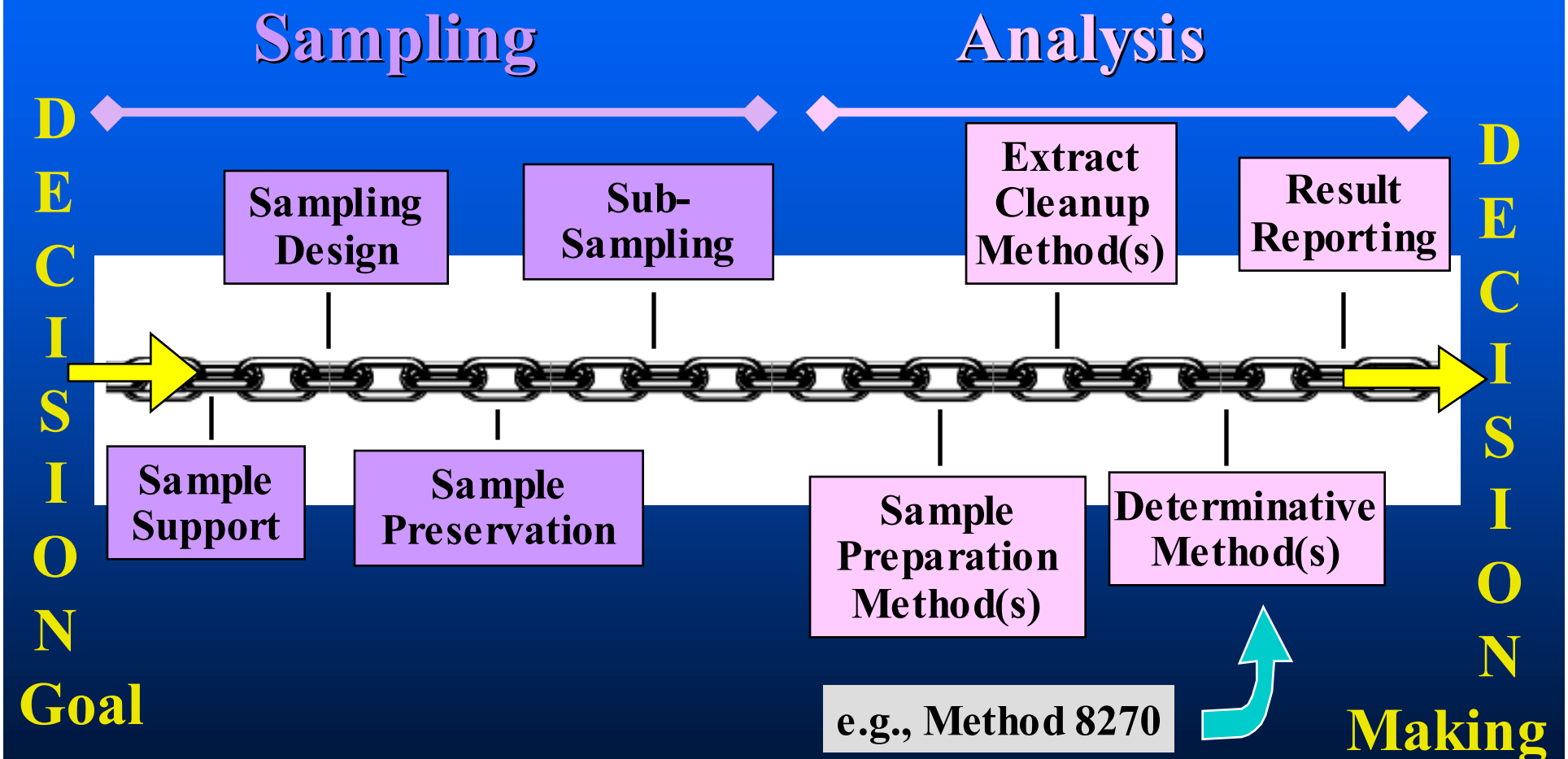


The decision driving sample collection:
Assess contamination resulting from atmospheric deposition

Example of Variability: Sample Location vs. Analytical Method



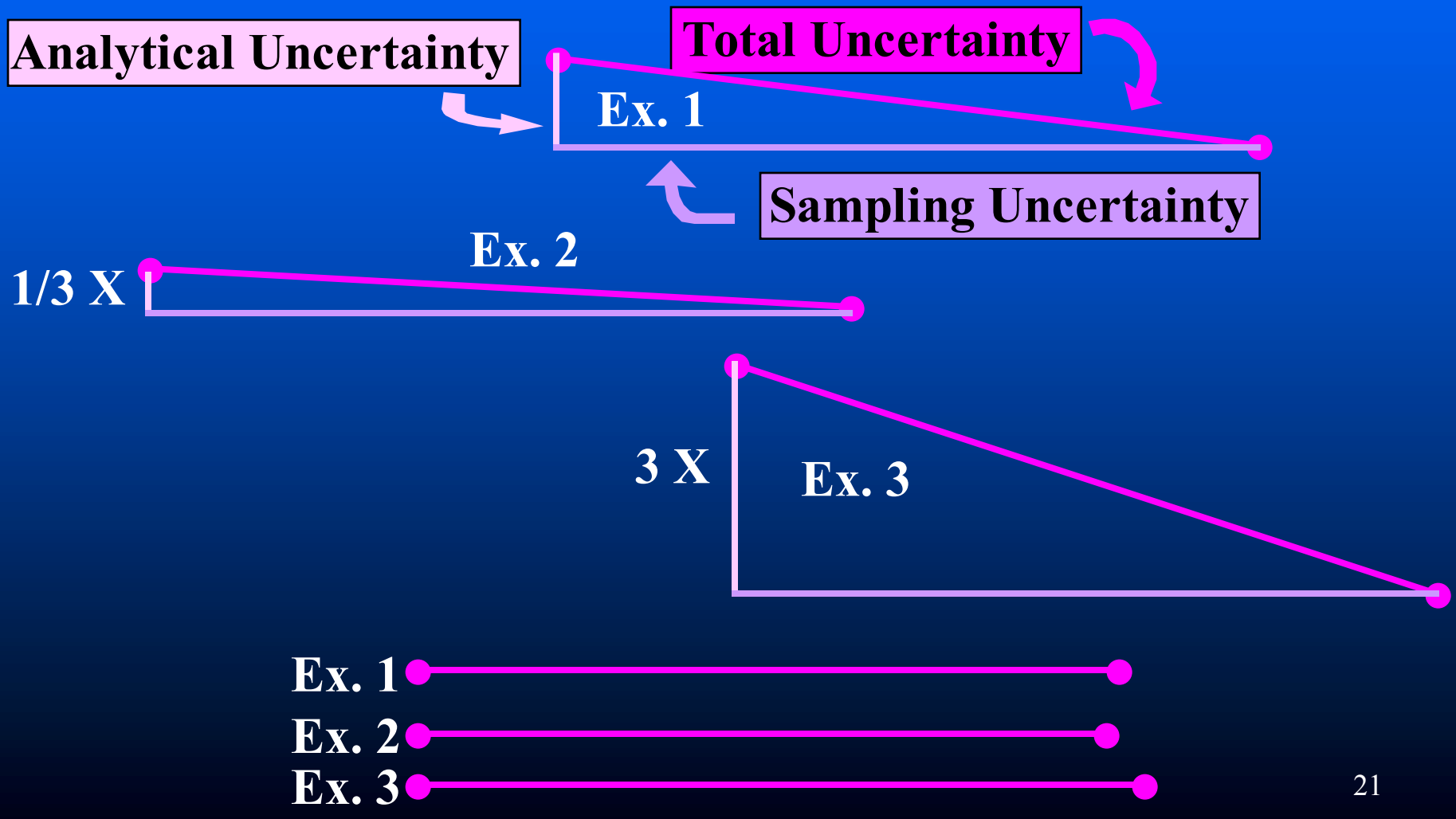
The Data Quality "Chain"



All links in the Data Quality chain must be intact for Decision Quality to be supported !

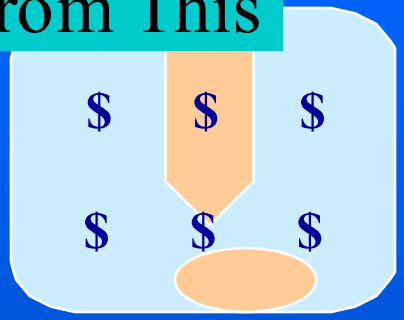
Summing Uncertainties

Uncertainties add according to ($a^2 + b^2 = c^2$)



Improve Decision Quality--Manage Uncertainties

From This

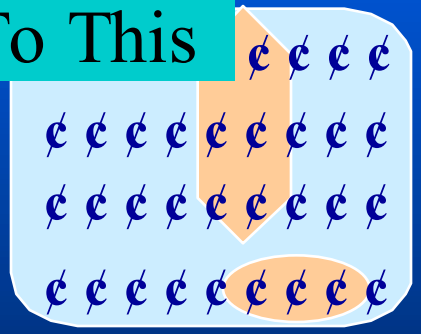


Fixed Lab Analytical Uncertainty

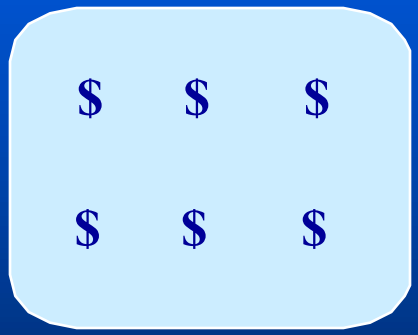
Ex 1

Sampling Uncertainty

To This



Remove hot spots



Field Analytical Data

Ex 2

Fixed Lab Data

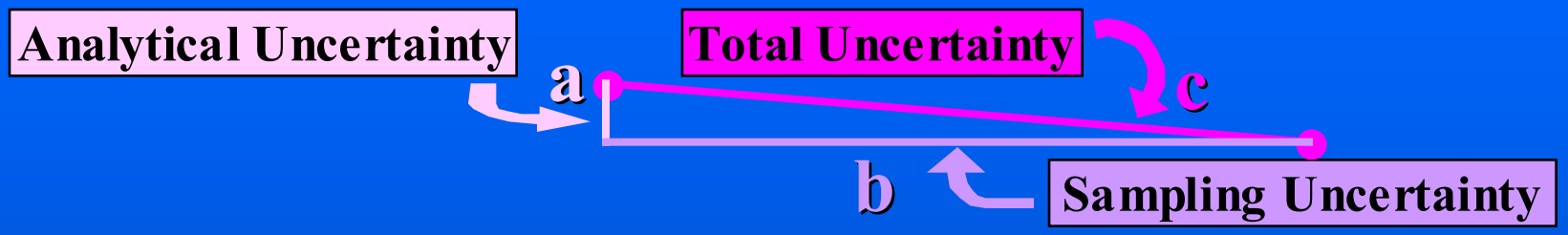
Ex 3

Decreased Sampling Variability after Removal of Hotspots

Sampling Uncertainty Controlled through Increased Density

Ex 1
Ex 2
Ex 3

Partitioning Data Uncertainty

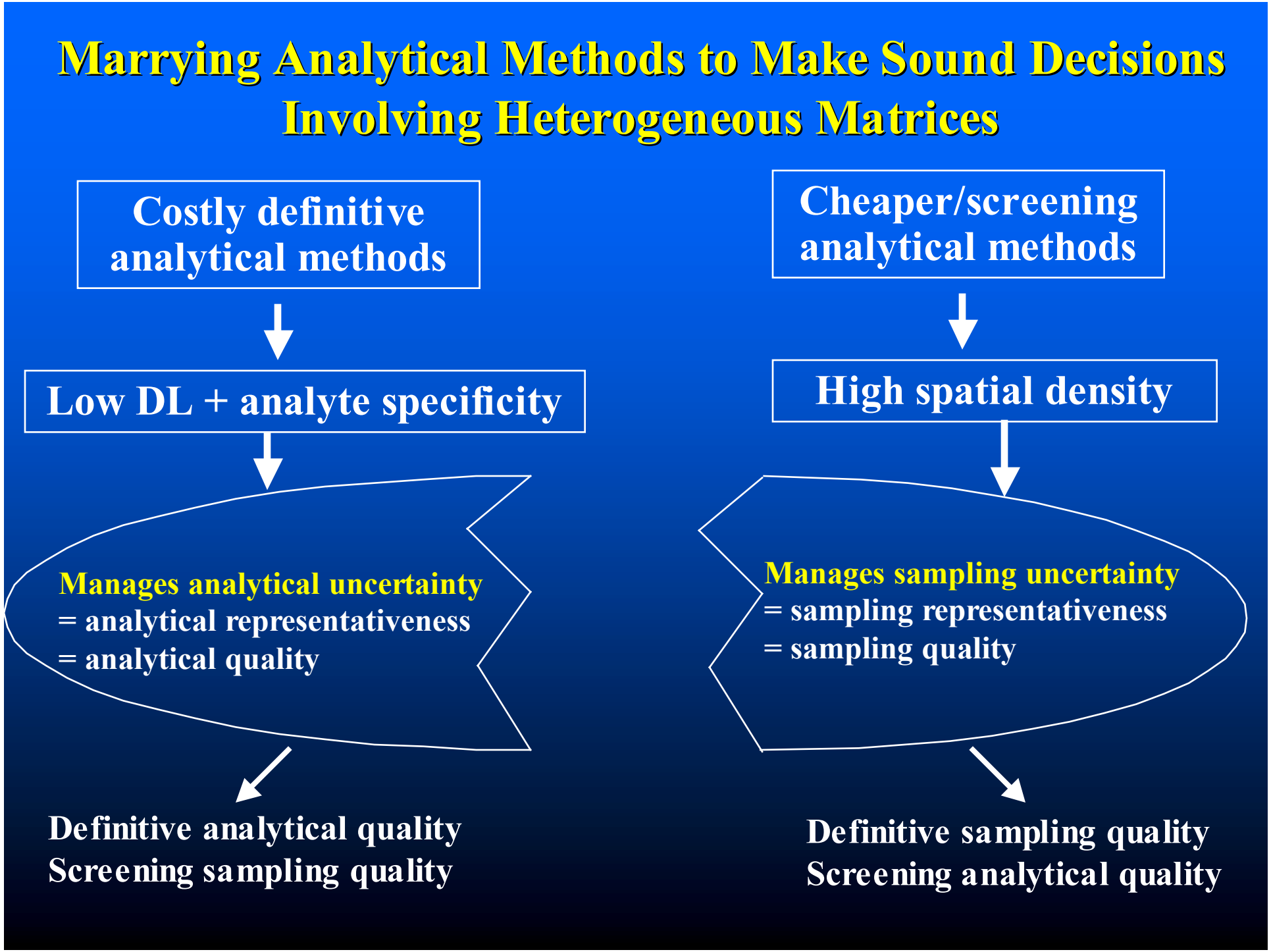


Example: Brownfields Project (Scrap Yard Site)

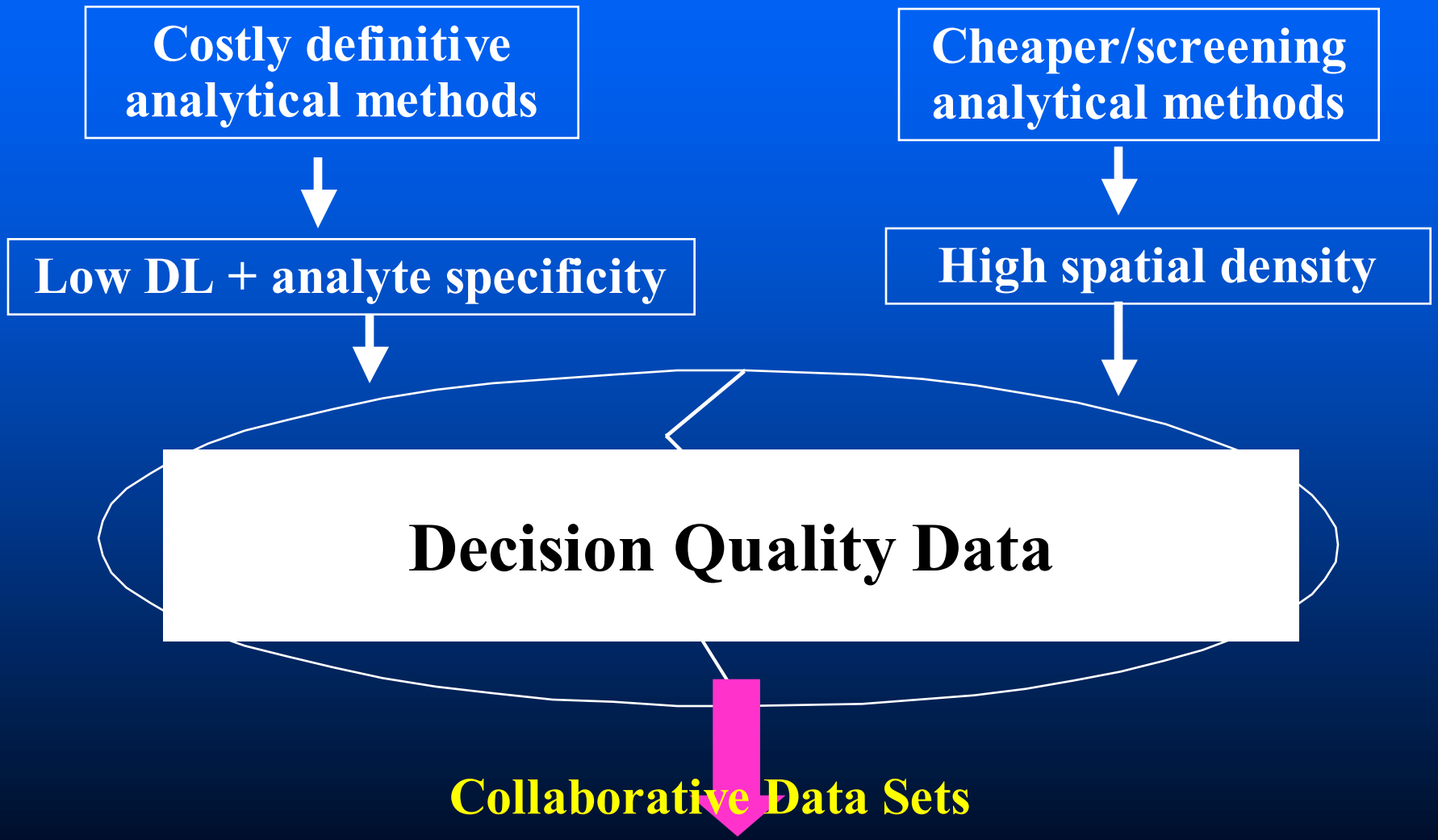
Std Dev $_{Sampling}$: Std Dev $_{Analytical}$ = Samp:Anal Ratio

Using LCS data	As	22.4 : 7 = 3 : 1
	Pb	3255 : 3 = 1085 : 1
Using LCS data	B(a)P	6,520 : 4.4 = 1464 : 1
Using MS/MSD data		6,520 : 12.7 = 513 : 1

Marrying Analytical Methods to Make Sound Decisions Involving Heterogeneous Matrices



Marrying Analytical Methods to Make Sound Decisions Involving Heterogeneous Matrices



Sample Representativeness is Key!

Finally able to address **defensibly and affordably!**

- **Cheaper analyses permit increased sample density**
  - New software for statistical/geostatistical decision support
    - » VSP software pkg FREE: http://dqo.pnl.gov/VSP/index.htm
    - » SADA software pkg FREE: http://www.tiem.utk.edu/~sada/
    - » FIELDS/SADA software: http://www.epa.gov/region5fields/static/pages/index.html
- **Real-time measurements support real-time decision-making**
  - Rapid feedback for course correction → smarter sampling
- **Data Quality: Focus on overall data uncertainty; analytical uncertainty usually a small fraction**

Case Study: Wenatchee Tree Fruit Site

- Pesticide IA kits guide dynamic work plan: remove and segregate contaminated soil for disposal

230 **IA analyses** (w/ thorough QC) **+** 29 **fixed-lab** samples for 33 analytes

Managed **sampling uncertainty**: achieved very high confidence that all contamination above action levels was located and removed

Managed **field analytical uncertainty** as additional QC on critical samples: confirmed & perfected field kit action levels)

- Clean closure data set
  - 33 fixed lab samples for analyte-specific pesticide analysis
  - Demonstrate full compliance with all regulatory requirements for all 33 pesticide analytes to >95% statistical confidence the first time!
- Projected cost: ~$1.2M; Actual: $589K (Save ~ 50%)
- Field work completed: <4 months; single mobilization

http://cluin.org/char1_edu.cfm#site_char

Terminology to Integrate Data Quality into Decision Quality

"Data Quality" Terminology

Current terminology usage does not focus on the goal of decision quality

- Irony: Great focus on the quality of data points; but overall quality of decisions easily unknown.
- Current usage does not distinguish
  - Methods vs. data vs. decisions
  - The factors that impact each step in the process
  - Relationships between different aspects of quality

Misleading Terminology

This term & an oversimplified data quality model falsely implies that:

- **All methods run in the field are screening methods.**
- **Therefore, all data produced in the field are of screening quality.**
- **Fixed labs using definitive analytical methods don't produce screening quality data.**
- **Fixed labs don't use screening methods.**

"Effective Data"
"Decision Quality Data"

Data of

known quality

that can be logically demonstrated to be

effective for making the specified decision

because both the

sampling and analytical uncertainties

are managed to the degree necessary to meet clearly

defined (and stated) decision confidence goals

Proposed Clarification of Terms Quality Assurance

- **Project QA:** ID causes of potential intolerable decision errors & the strategies to manage and prevent those decision errors
- **Data QA:** manage **both** sampling and analytical uncertainties to degree needed to avoid decision errors
  - Analytical representativeness evaluated, including impact of sample/matrix effects on analytical performance
  - Sample representativeness evaluated
- **Lab QA:** manage technical performance of analytical instruments, processes, and operators to meet lab quality goals
  - Sample/matrix effects on analytical performance may or may not be evaluated—depends on contract specifications.

Proposed Clarification of Terms
Data Quality

- Decision quality data* = Effective data* = data shown to be effective for decision-making
- Screening quality data* = some useful information provided; but too uncertain to support decision-making alone
- Collaborative data sets = distinct data sets used in concert with each other to co-manage sampling and/or analytical uncertainties to an acceptable level

* Includes sampling uncertainty. Nature of method irrelevant.

Transitioning to a More Modern Approach

Transition Steps

- **Articulate an overall vision and strategy to modernize site cleanup activities and programs**
  - View Triad pilot projects as both teaching and learning tools: perfect scientific best practice 1st, then write technical guidance
- **Revise and clarify the data quality model to match current scientific understanding**
  - Use intuitive terminology that avoids misconceptions, and that clarifies (rather than obscures) critical concepts
  - Conceptually link data quality to managing decision uncertainty
  - Retool common phrasing. Example: "Define the nature and extent of contamination **at the scale of decision-making**"
- **Educate about uncertainty management (decisions & data)**
- **Explicitly support multi-disciplinary project teams**

TIO Efforts to Provide Support

- **Outreach– published articles (reprints available on Clu-In)**
  - Environmental Testing & Analysis article (Jan 2001)
  - ES&T feature article (Oct 2001)
- **"PM's Handbook of Triad Best Practices" (in development—pilot draft Web-available Aug 1, 2002)**
  - Hyper-linked Internet-based "how-to" map to existing guidance and technical information that support Triad implementation
  - The "Handbook" is designed to evolve and incorporate new ideas as practitioner and programmatic experience grows
- **Partnering with other experts/organizations:**
  - US Army Corps of Engineers (Handbook partner)
  - Argonne National Lab (technical support and practitioner expert)
- **Internet seminars: http://cluin.org/studio/seminar.cfm**
  - Archived or live

The Diffusion of Innovation

"At first people refuse to believe that a strange new thing can be done, then they begin to hope it can be done—then it is done and all the world wonders why it was not done centuries ago."

—Francis Hodges Burnett